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(54) Applying bond coat to engine components using cold spray

(57) A process for applying a coating to a component (10) used in an engine is provided. The process includes the steps of providing a component (10) with at least one surface (24) to be coated, and depositing at least one layer of powder coating material onto the at least one surface (10) using a non-oxidizing carrier gas so that the powder coating material plastically deforms without melting and bonds to the at least one surface upon impact with the at least one surface. The process of the present invention has particular utility in applying bond coats to airfoil portions of turbine blades or vanes and to applying bond coats to combustion chamber liners.

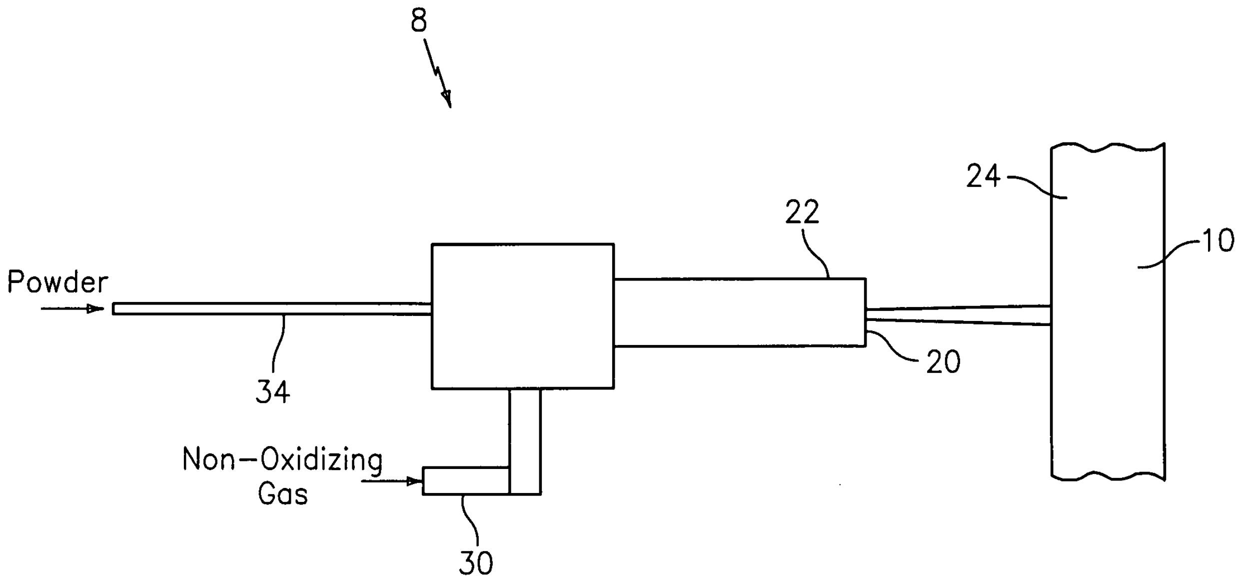

FIG. 1

EP 1 705 266 A2

Description

BACKGROUND OF THE INVENTION

(1) Field of the Invention

[0001] The present invention relates to a process for applying a coating to a component, such as a turbine blade or a combustion chamber liners, used in an engine.

(2) Prior Art

[0002] Currently, bond coats are applied using low-pressure plasma spray (LPPS). Operation and maintenance of LPPS systems is expensive and time consuming, limiting throughput. Also, LPPS requires a vacuum chamber. The size of a given chamber limits the size of the parts that can be processed.

[0003] Cold gas dynamic spraying or "cold spray" has been recently introduced as a new metallization spray technique to deposit powder metal without inclusions onto a substrate. A supersonic jet of helium and/or nitrogen is formed by a converging/diverging nozzle and is used to accelerate the powder particles toward the substrate to produce cold spray deposits or coatings. Deposits adhere to the substrate and previously deposited layers through plastic deformation and bonding. U.S. Patent Nos. 5,302,414 and 6,502,767 illustrate cold gas dynamic spraying techniques.

SUMMARY OF THE INVENTION

[0004] Accordingly, it is an object of the present invention to provide a process for applying a coating to a component used in an engine which reduces cycle times and maintenance costs.

[0005] It is a further object of the present invention to provide a process as above which can be used with any size component.

[0006] The foregoing objects may be attained using the process of the present invention.

[0007] In accordance with the present invention, a process for applying a coating, such as a bond coat, to a component used in an engine is provided. The process broadly comprises providing a component with at least one surface to be coated, and depositing at least one layer of powder coating material onto the at least one surface using a non-oxidizing carrier gas so that the powder coating material plastically deforms without melting and bonds to the at least one surface upon impact with the at least one surface. The process of the present invention has particular utility in applying bond coats to airfoil portions of turbine blades, vanes or combustion chamber liners for protection against oxidation.

[0008] Other details of the technique for applying a bond coat to engine components using cold spray of the present invention are set forth in the following detailed description and the accompanying drawings wherein like reference numerals depict like elements.

BRIEF DESCRIPTION OF THE DRAWINGS

[0009]

FIG. 1 is a schematic representation of an apparatus for depositing cold sprayed powder metal materials onto a component used in an engine; and

FIG. 2 is a photomicrograph of cold sprayed bond coat material at a magnification of 200X.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT(S)

[0010] The present invention relates to a process for applying a coating to a component used in an engine. For example, the process of the present invention may be used to apply a MCrAlY coating to at least one surface of an airfoil portion on a turbine blade where M is Ni and/or Co or a variation. It may also be used to apply a bond coat to a combustion chamber liner used in rocket engines.

[0011] The cold spray process for depositing powdered materials onto portions of a component which needs to be restored is advantageous in that it provides sufficient energy to accelerate particles to high enough velocities such that, upon impact, the particles plastically deform and bond to the surface of the component being restored or onto a previously deposited layer. The cold spray process allows the build up of a relative dense coating or structural deposit. Cold spray does not metallurgically transform the particles from their solid state.

[0012] When preparing to coat an article or component, it is often necessary to remove any pre-existing coating on the article or component. Any suitable stripping technique may be used to remove any pre-existing coating and to provide a fresh surface to which a coating material can be deposited. For example, any pre-existing coating may be stripped using mechanical or chemical techniques.

[0013] Referring now to FIG. 1, there is shown a system 8 for depositing a powder coating material onto a surface 24 of an article or component 10 to be coated. The article or component may be a turbine blade or vane used in a turbine engine. The system 8 includes a spray gun 22 having a converging/diverging nozzle 20 through which the powdered coating material is sprayed onto the surface 24. The article or component 10 may be formed from any suitable material known in the art. In the case of a turbine blade or vane, the article or component 10 may be formed from a superalloy material such as a nickel based alloy. In the case of a combustion chamber liner, the article or component 10 may be formed from a nickel or copper-based alloy. During the coating operation, the article or component 10 may be held stationary or may be articulated, rotated, or translated by any suitable means (not shown) known in the art.

[0014] In the process of the present invention, the material to be deposited is a powdered material. The powdered coating material may comprise any suitable coating material known in the art. For example, the coating material can be a MCrAlY material where M is nickel or cobalt, such as NiCoCrAlY, NiCrAlY or CoCrAlY. The coating material may be a copper alloy such as a copper-chromium alloy or a copper-chromium-aluminum alloy. The coating material may form a stand alone coating or a bond coat for metallic and ceramic overcoats.

[0015] The powdered coating materials that are used to form the deposit on the surface 24 may have a diameter of 5-80 microns, preferably a diameter of 10 microns or less if the alloy material being deposited is hard. In a most preferred embodiment, the powdered coating materials has a diameter in the range of from about 5.0 microns to 10 microns. Smaller particle sizes enable the achievement of higher particle velocities. Below 5 microns in diameter, the particles risk getting swept away from the surface 24 due to a bow shock layer above the surface 24, i.e. insufficient mass to propel the particle through the bow shock. The narrower the particle size distribution, the more uniform the particle velocity will be. This is because the smaller particles in the spray/plume will hit the slower, larger ones and effectively reduce the velocity of both.

[0016] The particles to be deposited may be accelerated to supersonic velocities using compressed gas, such as a gas selected from the group consisting of helium, nitrogen, another inert gas, and mixtures thereof. Helium is a preferred gas because it produces the highest velocity due to its low molecular weight.

[0017] The bonding mechanism employed by the process of the present invention for transforming the powdered coating material into a deposit is strictly solid state, meaning that the particles plastically deform but do not melt. Any oxide layer that may have formed on the particles, or is present on the surface 24, or is present in a previously deposited layer, is broken up and fresh oxide-free contact is made at very high pressures.

[0018] The powdered coating material used to form the deposit may be fed to the spray gun 22 using any thermal spray feeder known in the art with the capability to feed the powder or the stated size. One such feeder that may be used is manufactured by Powder Feed Dynamics of Cleveland, Ohio. This feeder has an auger type feed mechanism. Fluidized bed feeders and barrel roll feeders with an angular slit may also be used.

[0019] In the process of the present invention, the feeder may be pressurized with a gas selected from the group consisting of helium, nitrogen, another inert gas, and mixtures thereof. Feeder pressures are generally 15 psi (103 kPa) above the main gas or head pressures, which pressures are usually in the range of from 200 psi (1.38 MPa) to 500 psi (3.45 MPa), depending on the powdered coating material composition. The main gas is preferably heated so that gas temperatures are in the range of from 600 degrees Fahrenheit (315°C)to 1200 degrees Fahrenheit (649°C). If desired, the main gas may be heated as high as approximately 1250 degrees Fahrenheit (677°C) depending on the material being deposited. The gas may be heated to keep it from rapidly cooling and freezing once it expands past the throat of nozzle 20. The net effect is a surface temperature on the article or component 10 of about 115 degrees Fahrenheit (46°C) during deposition. Any suitable means known in the art may be used to heat the gas.

[0020] To deposit the powdered coating material, the nozzle 20 may pass over the surface 24 of the article or component 10. The number of passes is a function of the thickness of the material to be applied. The process of the present invention is capable of forming a deposit having any desired thickness.

[0021] The main gas that is used to deposit the powdered metal particles onto the surface 24 may be passed through the nozzle 20 via inlet 30 at a flow rate of from 0.001 SCFM (0.028 1/m) to 50 SCFM (1416 l/m), preferably in the range of from 15 SCFM (425 1/m) to 35 SCFM (991 l/m). The foregoing flow rates are preferred if helium is used as the main gas. If nitrogen is used by itself or in combination with helium as the main gas, the nitrogen may be passed through the nozzle 20 at a flow rate of from 0.001 SCFM (0.028 l/m) to 30 SCFM (849 l/m), preferably from 4.0 SCFM (113 l/m) to 30 SCFM (849 l/m), more preferably 4.0 SCFM (113 l/m) to 8.0 SCFM (227 l/m).

[0022] The main gas temperature may be in the range of from 600 degrees Fahrenheit (315°C) to 1200 degrees Fahrenheit (649°C), preferably from 700 degrees Fahrenheit (371°C) to 1000 degrees Fahrenheit (539°C), and most preferably from 725 degrees Fahrenheit (385°C) to 900 degrees Fahrenheit (482°C).

[0023] The pressure of the spray gun 22 may be in the range of from 200 psi (1.38 MPa) to 500 psi (3.45 MPa), preferably from 200 psi (1.38 MPa) to 400 psi (2.76 MPa), and most preferably from 275 psi (1.80 MPa) to 375 psi (2.59 MPa). The powdered coating material is preferably fed from a hopper, which is under a pressure in the range of from 10 (69 kPa) to 50 psi (345 kPa) higher than the specific main gas pressure, preferably 15 psi (103 kPa) higher, to the spray gun 22 via line 34 at a rate in the range of from 10 grams/min to 100 grams/min, preferably from 10 grams/min to 50 grams/min.

[0024] The powdered coating material is fed to the spray gun 22 using a non-oxidizing carrier gas. The carrier gas may be introduced via inlet 30 at a flow rate of from 0.001 SCFM (0.028 1/m) to 50 SCFM (1416 l/m), preferably from 8.0 SCFM (227 1/m) to 15 SCFM (425 l/m). The foregoing flow rate is useful if helium is used as the carrier gas. If nitrogen by itself or mixed with helium is used as the carrier gas, a flow rate of from 0.001 SCFM (0.028 1/m) to 30 SCFM (849 1/m), preferably from 4.0 to 10 SCFM (113 l/m to 238 l/m), may be used.

[0025] The spray nozzle 20 is held at a distance from the surface 24. This distance is known as the spray distance and may be in the range of from 10 mm. to 50 mm.

[0026] The velocity of the powdered coating particles leaving the spray nozzle 20 may be in the range of from 825 m/s to 1400 m/s, preferably from 850 m/s to 1200 m/s.

[0027] The process of the present invention is advantageous over the current LPPS processes. For example, in LPPS, the powder is melted. In the process of the present invention, the powder is not melted. Still further, LPPS requires the use of a vacuum chamber which limits the size of the article or component which can be coated. The process of the present invention does not require a vacuum chamber and may be performed in the open. As a result, there is no restriction on the size of the article or component which can be coated. In LPPS, it is possible to have deposits which include oxides that may render the coating brittle. In the process of the present invention, no such oxides are formed. Still another advantage of the cold spray process of the present invention is that the as-deposited coating is at least 97% dense. Still further, coated articles may be capable of having a bond strength capable of 10 ksi.

[0028] The process of the present invention may be used to form any type of coating. For example, the process may be employed to form a MCrAlY bond coat on an airfoil portion and/or some other portion of a blade or vane used in a turbine engine, such as a gas turbine engine.

[0029] FIG. 2 is a photograph of a cold spray deposited NiCrAlY coating 100. The coating was formed by using powdered NiCrAlY coating material having a mean particle size of 10 microns using a helium gas at a pressure of 320 psi (2.21 MPa) at a temperature of 850 degrees Fahrenheit (454 degrees Centigrade). The coating material particles were fed at a rate of 25 grams/min. The spray nozzle was spaced from the surface being coated by a distance of 1.0 inches (25.4 mm). The nozzle was traversed at a speed of 50 inches (1.27 m) per minute with a step size of 0.030 inches (0.76 mm). The substrate material 102 was Inconel 718, 0.125 inches (3.175 mm) thick. The applied NiCrAlY coating thickness was 0.015 inches (0.38 mm).

[0030] It is also possible to find a MCrAlY bond coat on an article or component using helium at a pressure of 320 psi (2.21 MPa) and at a temperature of about 970 degrees Fahrenheit (about 520 degrees Centigrade).

[0031] When the cold spray process is used to apply a bond coat, an additional coating layer or layers may be formed over the bond coat. Any suitable technique known in the art may be used to apply the overcoat layer(s). The overcoat materials make be metallic or ceramic in composition.

[0032] The cold spray process offers many other advantages over other processes. Since the powders are not heated to high temperatures, no oxidation, decomposition, or other degradation of the feedstock materials occurs. Other potential advantages include the formation of compressive residual surface stresses and retaining the microstructure of the feedstock. Also, because relatively low temperatures are used, thermal distortion of the substrate will be minimized. Because the feedstock is not melted, cold spray offers the ability to deposit materials that cannot be sprayed conventionally due to the formation of brittle intermetallics or a propensity to crack upon cooling or during subsequent heat treatments.

[0033] Yet another advantage is that with cold spray, it is possible to spray over a blade/vane surface and not have the coating bridge the cooling holes in the surface. The ability to apply a coating in a repair/refurbish operation and not have to go back and clean out the holes, or at least greatly reduce the labor required to do this is a great advantage over current operations.

Claims

1. A process for applying a coating to a component (10) comprising the steps of:

   providing a component (10) having at least one surface (24) to be coated; and
   depositing at least one layer of powder coating material onto said at least one surface using a non-oxidizing carrier gas so that said powder coating material plastically deforms without melting and bonds to said at least one surface upon impact with said at least one surface.

2. The process according to claim 1, wherein said component providing step comprises providing a component (10) used in an engine having an airfoil portion and said depositing step comprises depositing said at least one layer on at least one surface of said airfoil portion.

3. The process according to claim 1 or 2, wherein said depositing step comprises providing said powder coating material in particle form having a particle size no greater than 10 microns and wherein said depositing step comprises accelerating said particles to a speed in the range of from 825 m/s to 1400 m/s.

4. The process according to claim 3, wherein said depositing step comprises providing said powder coating material in particle form having a particle size in the range of from 5.0 microns to 10 microns and wherein said accelerating step comprises accelerating said particles to a speed in the range of from 850 m/s to 1200 m/s.

5. The process according to claim 3 or 4, wherein said depositing step further comprises feeding said powdered coating material to a spray nozzle at a feed rate of from 10 grams/min to 100 grams/min using a carrier gas selected from the group consisting of helium, nitrogen, another inert gas, and mixtures thereof.

6. The process according to claim 5, wherein said feeding step comprises feeding said metal powder to said spray nozzle at a feed rate of from 10 grams/min to 50 grams/min.

7. The process according to claim 5 or 6, wherein said carrier gas is helium and said feeding step comprises feeding helium to said nozzle at a flow rate of from 0.001 SCFM (0.028 l/m) to 50 SCFM (1416 l/m).

8. The process according to claim 7, wherein said feeding step comprises feeding said helium to said nozzle at a flow rate in the range of from 8.0 SCFM (227 l/m) to 15 SCFM (425 l/m).

9. The process according to claim 5 or 6, wherein said carrier gas comprises nitrogen and said feeding step comprises feeding said nitrogen to said nozzle at a flow rate of from 0.001 SCFM (0.028 l/m) to 30 SCFM (849 l/m) .

10. The process according to claim 9, wherein said feeding step comprises feeding said nitrogen to said nozzle at a flow rate of from 4.0 SCFM (113 l/m) to 10 SCFM (283 l/m).

11. The process according to any of claims 5 to 10, wherein said depositing step comprises passing said powdered coating particles through said nozzle using a main gas selected from the group consisting of helium, nitrogen, another inert gas, and mixtures thereof at a main gas temperature in the range of from 600 degrees Fahrenheit (315°C) to 1200 degrees Fahrenheit (649°C) and at a spray pressure in the range of from 200 psi (1.38 MPa) to 500 psi (3.45 MPa).

12. The process according to claim 11, wherein said passing step comprising passing said powdered coating particles through said nozzle at a main gas temperature in the range of from 700 degrees Fahrenheit (371°C) to 1000 degrees Fahrenheit (538°C) at a spray pressure in the range of from 200 psi (1.38 MPa) to 400 psi (276 MPa) .

13. The process according to claim 11, wherein said main gas temperature is in the range of from 725 degrees Fahrenheit (385°C) to 900 degrees Fahrenheit (482°C) at a spray temperature in the range of from 275 psi (1.90 MPa) to 375 psi (2.59 MPa).

14. The process according to claim 11, 12 or 13, wherein said main gas comprises helium and said passing step comprises feeding said helium to said nozzle at a flow rate in the range of from 0.001 SCFM (0.028 1/m) to 50 SCFM (1416 1/m).

15. The process according to claim 14, wherein said helium feeding step comprises feeding said helium to said nozzle at a flow rate in the range of from 15 SCFM (425 l/m) to 35 SCFM (991 1/m) .

16. The process according to claim 11, 12 or 13, wherein said main gas comprises nitrogen and said passing step comprises feeding said nitrogen to said nozzle at a feed rate in the range of from 0.001 SCFM (0.028 l/m) to 30 SCFM (849 l/m).

17. The process according to claim 16, wherein aid nitrogen feeding step comprises feeding said nitrogen to said nozzle at a feed rate in the range of from 4.0 to 8.0 SCFM (113 1/m to 227 1/m) .

18. The process according to any preceding claim , wherein said depositing step comprises forming a bond coat on said component (10) having a bond strength in the range up to 10 ksi or greater.

19. The process according to any preceding claim, wherein said depositing step comprises depositing a MCrAlY material on said component (10).

20. The process according to any preceding claim, wherein said depositing step comprises depositing a coating which is at least 97% dense on said component.

21. The process according to any preceding claim, wherein said component providing step comprises providing an engine component having a plurality of cooling holes in a surface thereof; and said depositing step comprises depositing said at least one layer of powder coating material without bridging said cooling holes in said surface.

22. The process according to any preceding claim, wherein said component providing step comprises providing a combustion chamber liner and said depositing step comprises depositing said at least one layer on at least one surface of said combustion chamber liner.

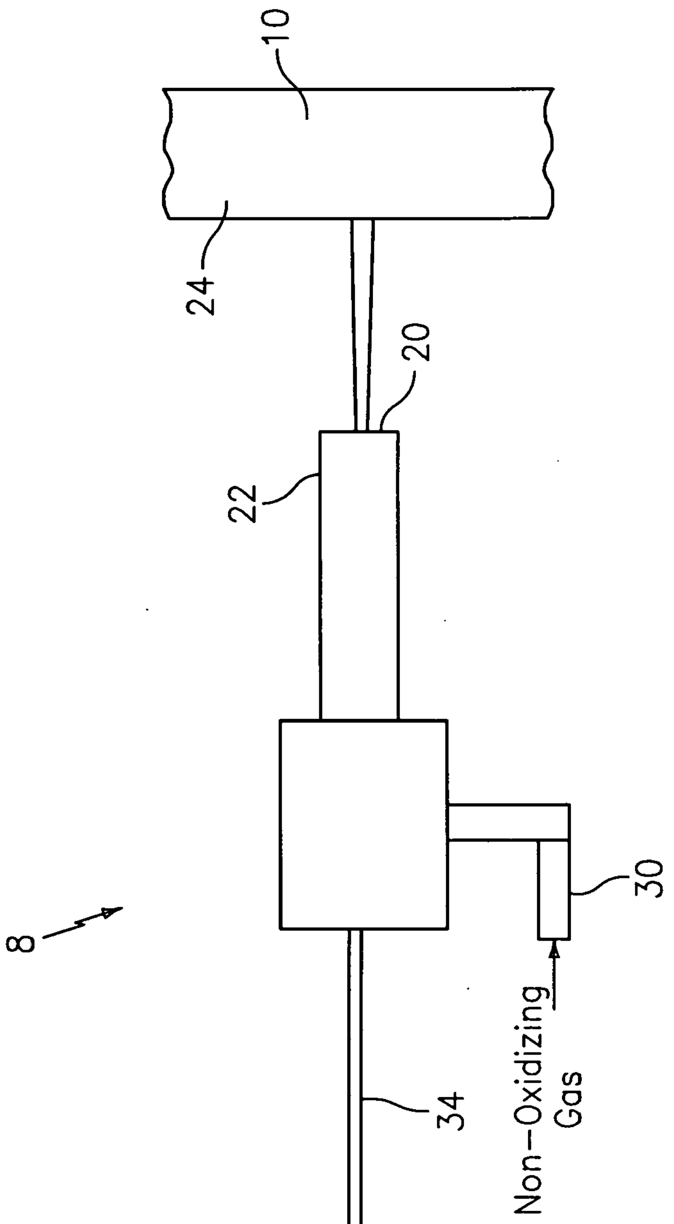

FIG. 1

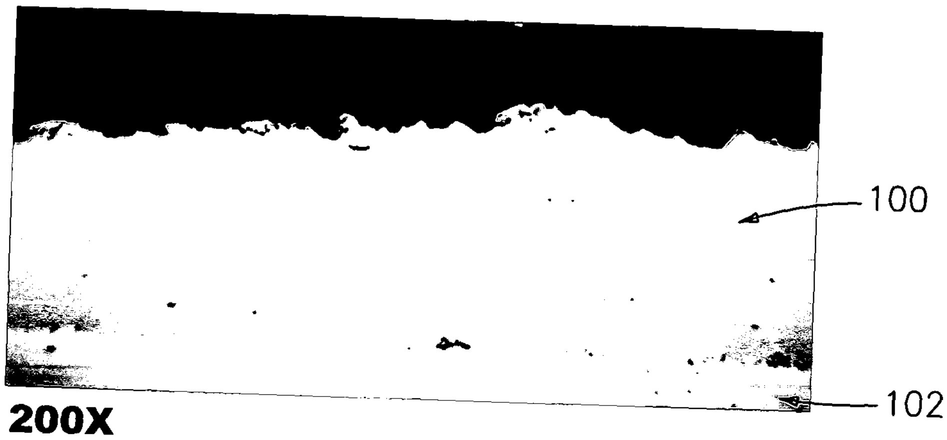

FIG. 2

REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

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